# Matrix-DBP for (m,k)-firm real time guarantee

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# Matrix-DBP For (m, k)-firm Real-Time Guarantee

Based on a common work with E. Poggi, YQ. Song, Z. Wang, A. Koubâa
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- Part 1: context
- Part 2: where are the problems
- Part 3: Matrix-DBP
- Part 4: future work

Presentation at

浙江大学 ZHEJIANG UNIVERSITY

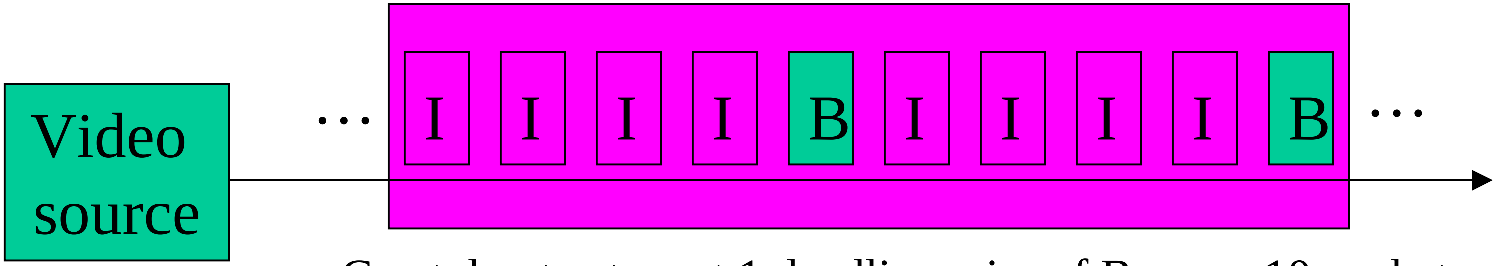
# Part 1: (m,k)-firm background

# Why we interest in (m,k)-firm?

- HRT uses WC analysis leading to over sized system design (pessimistic performance estimation)
- In practice, many systems being classified HRT are not so « hard ». Occasional deadline misses can be tolerated if they are correctly distributed

# Why we interest in (m,k)-firm?

- SRT can resolve the over-sizing problem but does not specify how deadlines can missed
- A probabilistic guarantee of m/k may not be sufficient (e.g. MPEG video stream composed of I, B and P packets)




Can tolerate at most 1 deadline miss of B every 10 packets
Probability of 9/10 can not be suitable

# Why we interest in (m,k)-firm?

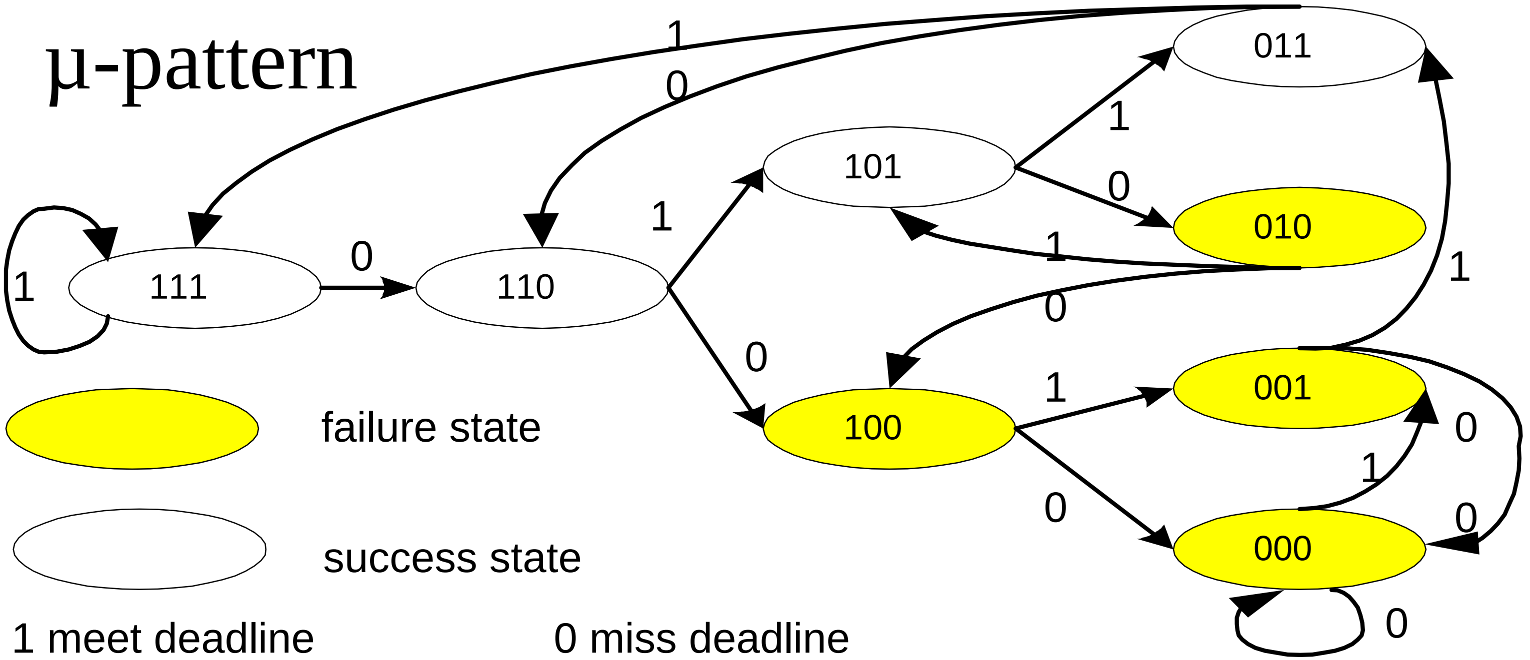
- (m,k)-firm guarantees the deadline meeting of *m* among any *k* consecutive task invocations or message transmissions
- (m,k)-firm provides a general frame for RT constraints description :
  - HRT is a particular case of (m,k)-firm with $m=k$
  - SRT guarantee with probability $p = m/k$ is a particular case of (m,k)-firm with: $p=\lim_{m,k\to\infty}\frac{m}{k}$

# (m,k)-firm and WHRT

- (m,k)-firm (i.e. at least m of k meets) is firstly introduced by [Hamdaoui95]
- WHRT is defined by [Bernat98] and [Bernat&Burns01] to generalize (m,k)-firm:
  - $\left(\overline{m}, \overline{k}\right)$: at most *m* misses. But $(m,k) = \left(\overline{k-m}, \overline{k}\right)$
  - <m,k>: in any *k* consecutive jobs, at least *m* consecutive jobs are with deadline meet
  - $\left\langle \overline{m}, \overline{k} \right\rangle = \left\langle \overline{m} \right\rangle$ : never *m* consecutive deadline misses (notice that $(m,k) \le \left\langle \overline{k-m} \right\rangle$ )

# (m,k)-firm

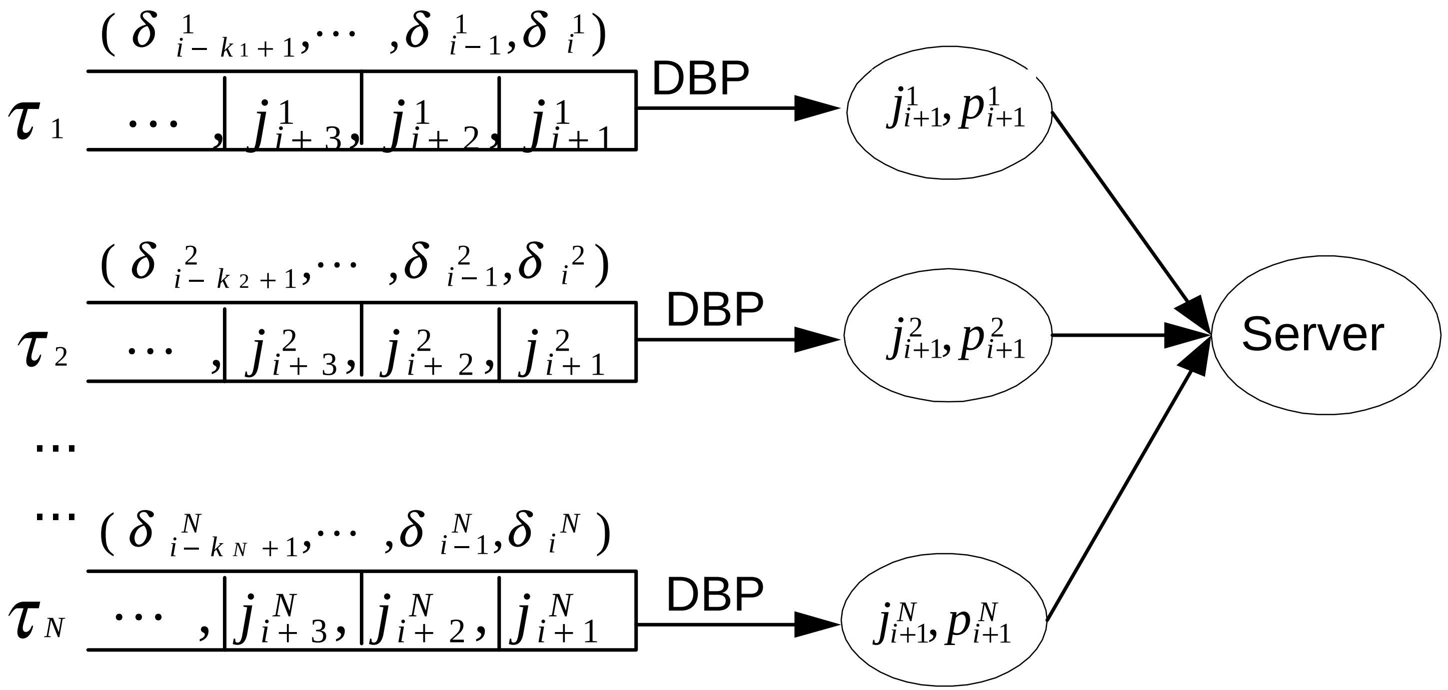
- Failure state in (m,k)-firm context
- Example of (2,3)-firm
- µ-pattern



# DBP: Distance Based Priority

- DBP of a μ-pattern is defined as the number of deadline misses to arrive to a failure state
- Example: (3,5)-firm
  - (11011) has a distance of 2
  - (10111) has a distance of 3
  - (10001) has a distance of 0

# DBP in MIQSS model




$j_i^x$ : $i_{th}$ instance of job x $\quad$ $p_i^x$ :priority of $i_{th}$ instance of job x

- A job is modeled by: $\tau_i = \{D_i, c_i, m_i, k_i\}$

# Gain of DBP for (m,k)-firm

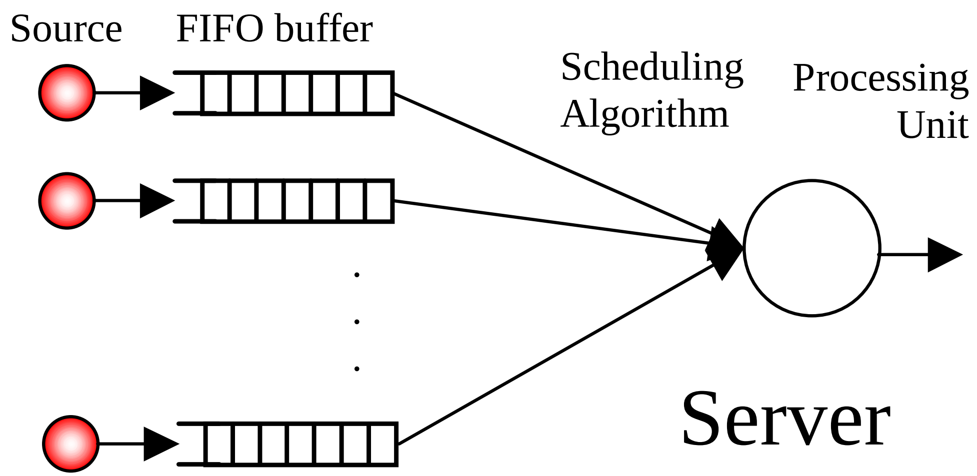
- Dynamic QoS control is possible with:
  - In case of overload, DBP allows on-line drop down of jobs according to $(m_i,k_i)$, reducing thus the need of resources, i.e.:

$$\sum_{i=1}^{N}\left[\frac{c_i}{T_i}\frac{m_i}{k_i}\right]\leq 1 \quad \text{instead of} \quad \sum_{i=1}^{N}\left[\frac{c_i}{T_i}\right]\leq 1$$

  - Can be extended to (m(t), k(t)) when on-line scheduling algorithm is adopted

# Part 2: where are problems?

# Problems of DBP in MIQSS for RT



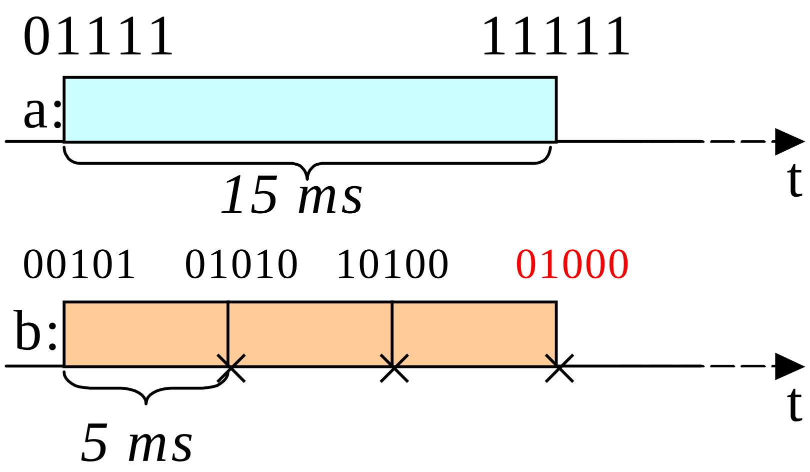

- A job is modeled by: $\tau_i = \{T_i, D_i, c_i, m_i, k_i\}$
- Pb1: how to choose when several jobs have the same priority? (DBP+EDF?)
- Pb2: how to take into account the relative importance among jobs of all sources ?

# Un example of Pb2

| | (m,k)-constraint | Service time (ms) | Period/ Deadline | Initial μ-pattern |
|---|---|---|---|---|
| **Sa** | (4,5) | 15 | 30 | {01111} |
| **Sb** | (2,5) | 2 | 5 | {00101} |

2

3




processing firstly Sa will lead to failure state of Sb !

**So notion of**
**relative criticality**
**should be defined**

# Need of new *non-preemptive* scheduling algo.

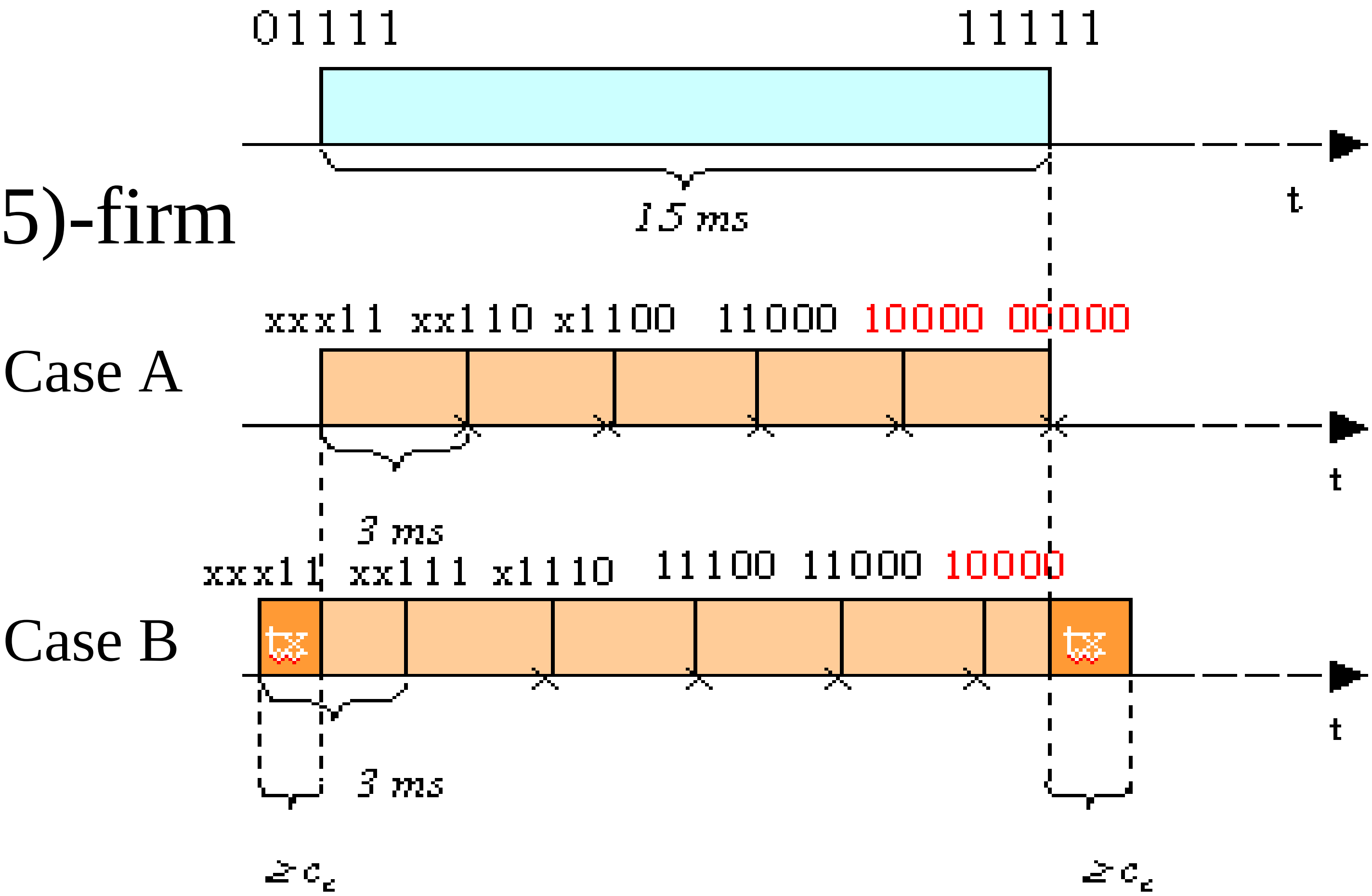
- Should take into account:
  - (m,k)-firm constraint
  - Other temporal parameters & constraints: $T_i$, $D_i$, $c_i$
  - Relative criticality between streams (a matrix can be used to represent it)
- Should be of low implementation cost

*Matrix-DBP can meet all these requirements*

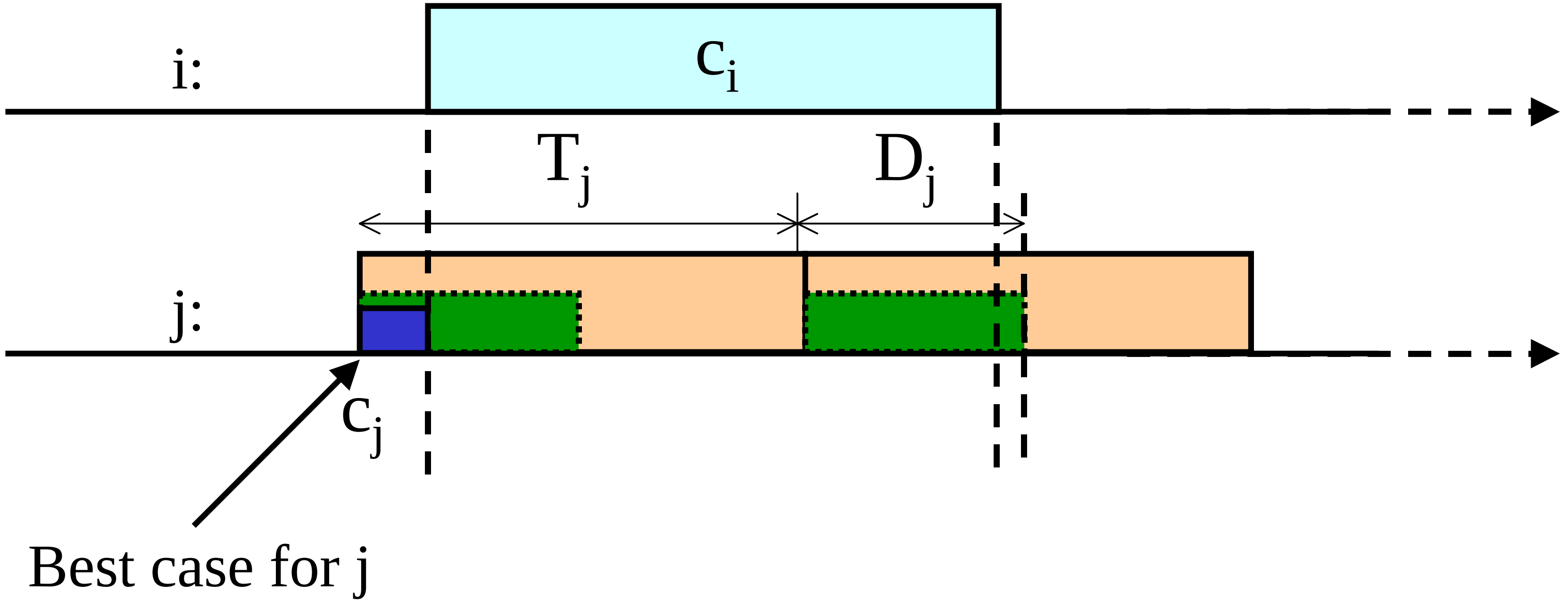
# Part 3: Matrix-DBP

# Offset between jobs invocations

(2,5)-firm



# When happens 1 deadline miss



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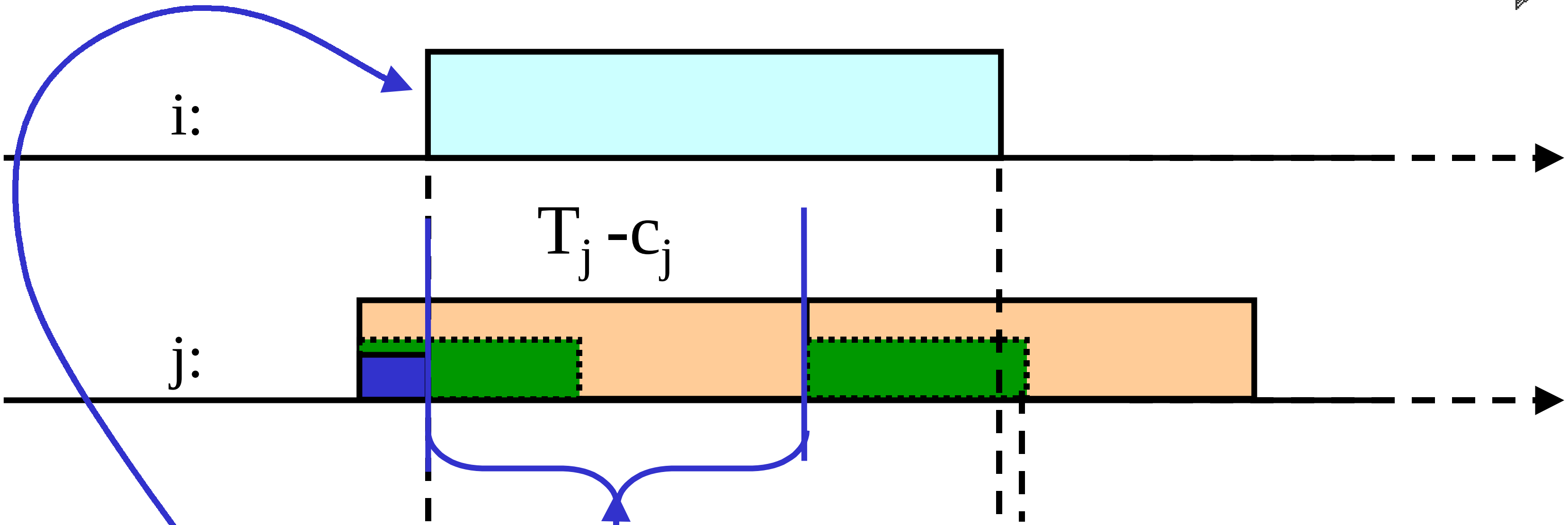
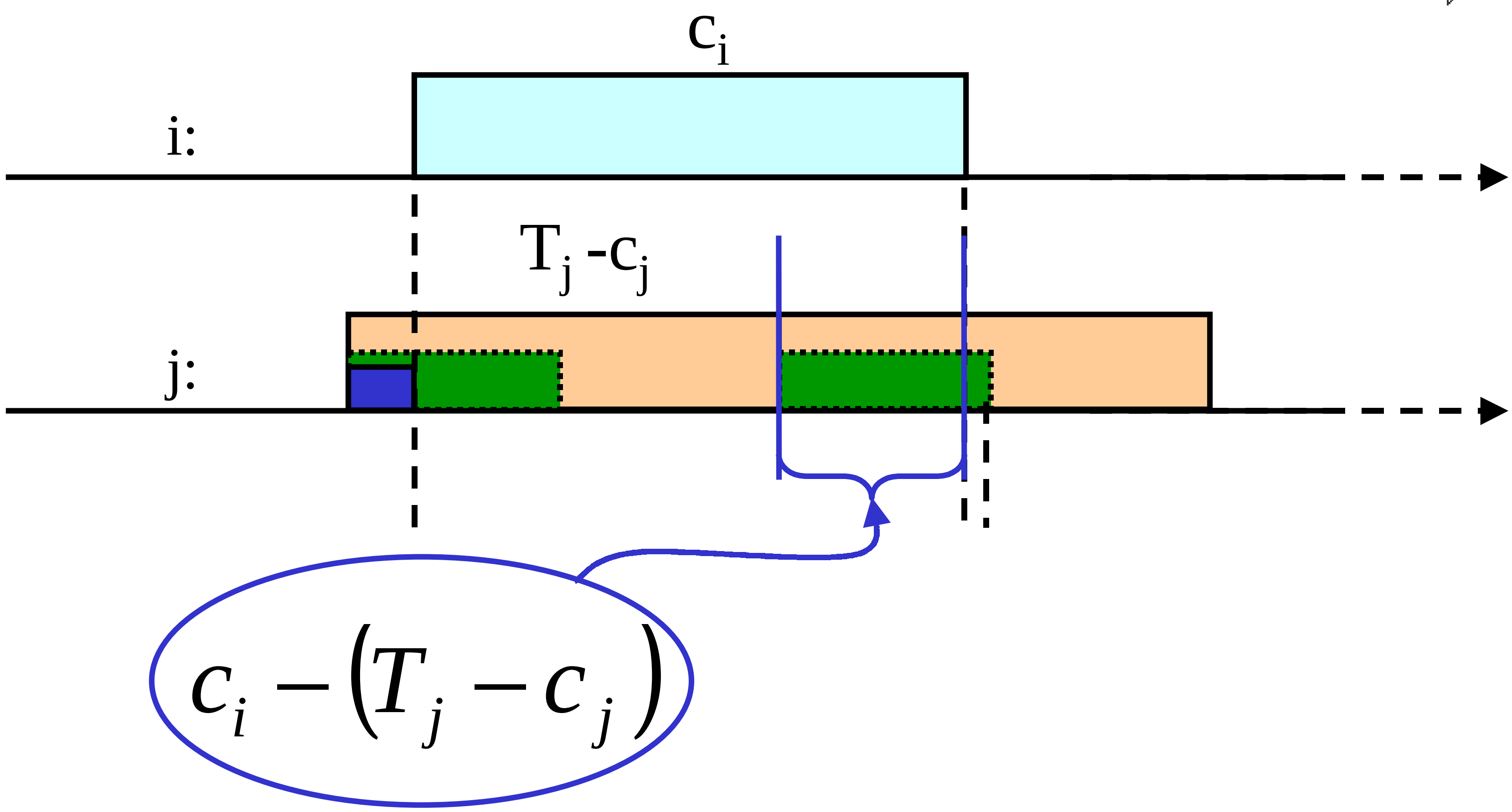
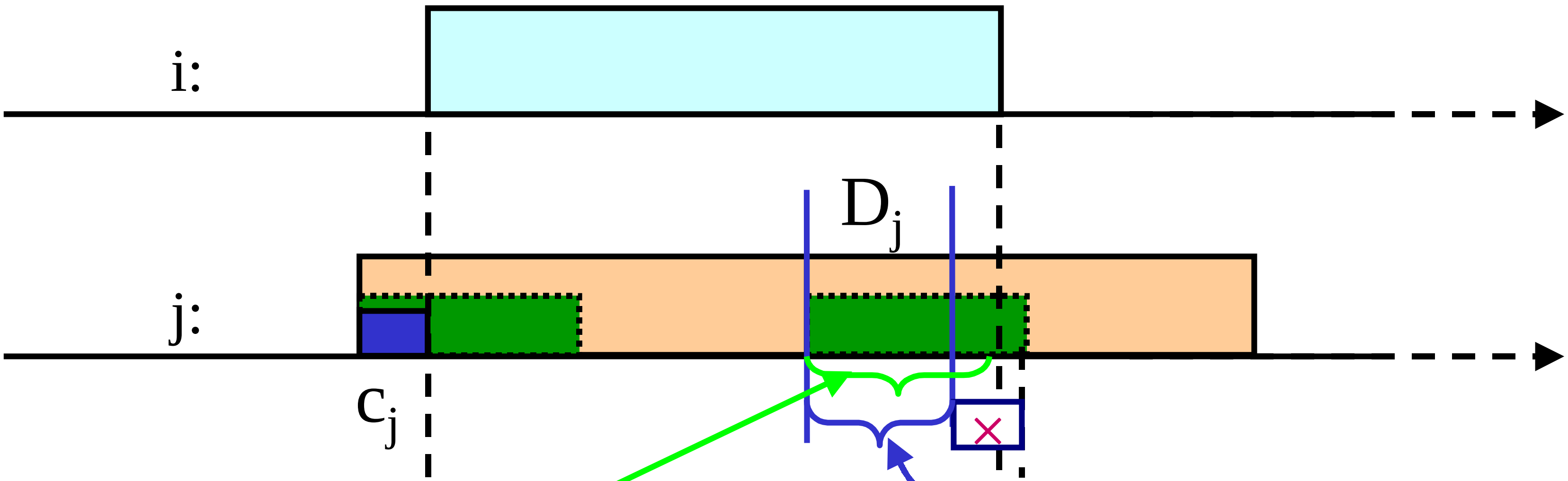



$$c_i - (T_j - c_j)$$

# When happens 1 deadline miss



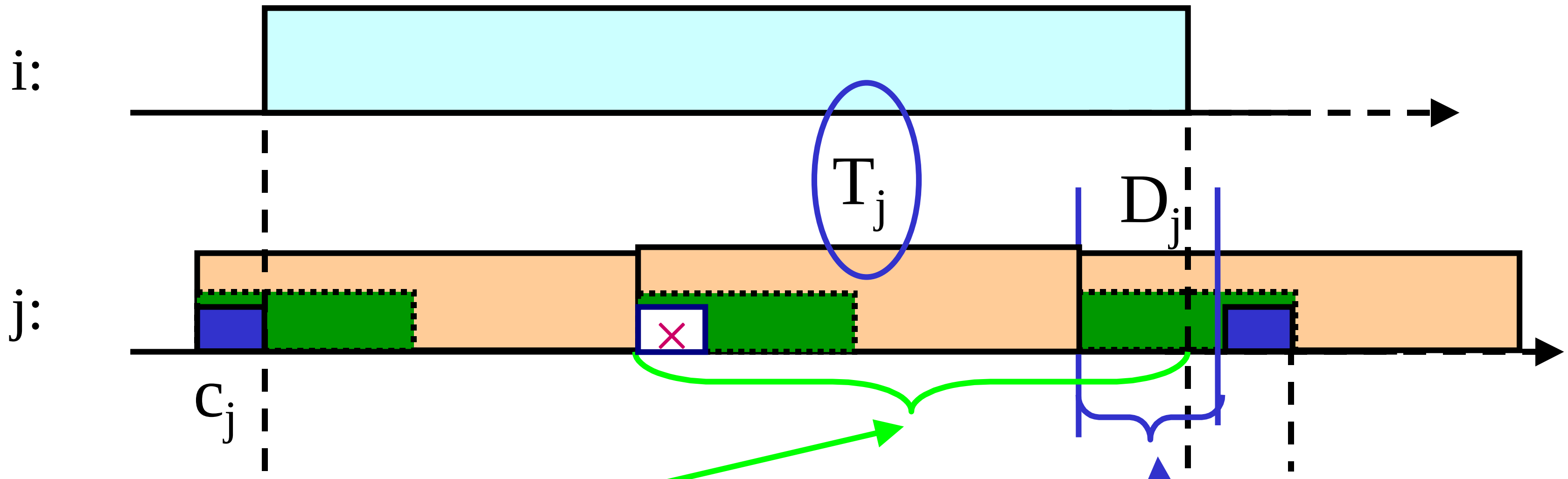
# When happens 1 deadline miss




if $$c_i - (T_j - c_j) > D_j - c_j,$$ then 1 miss in the best case.

i.e., at least 1 miss

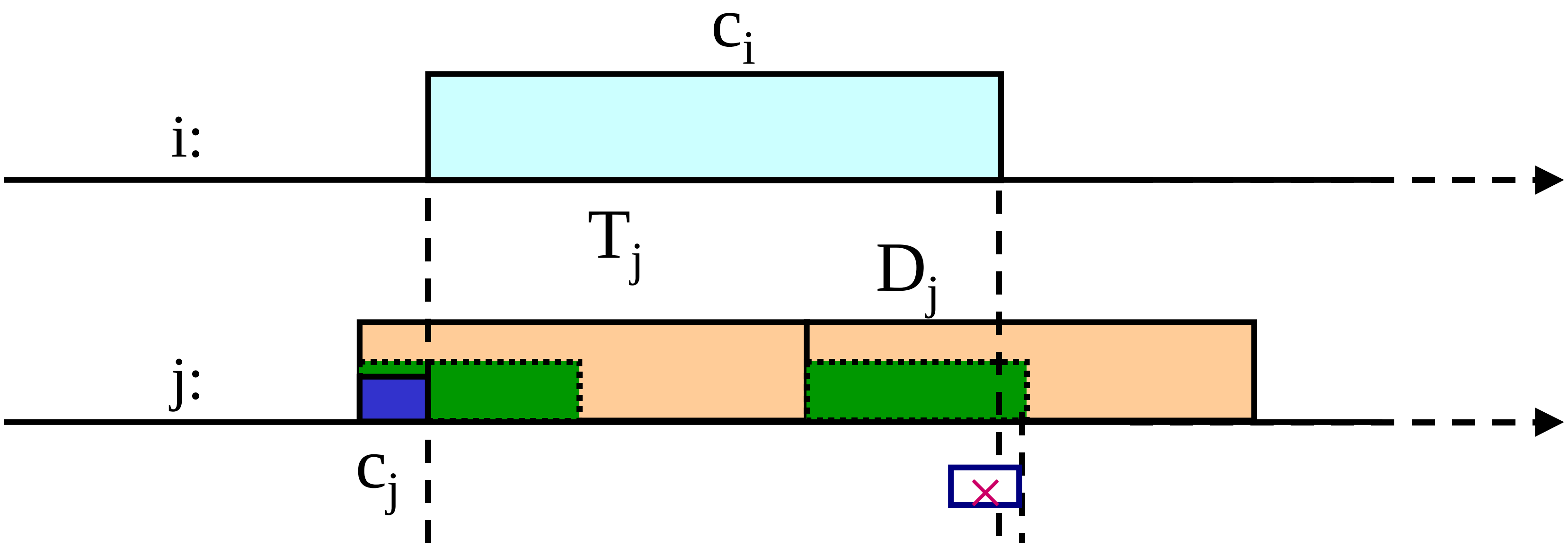
# When happens 1 deadline miss




if $c_i - (T_j - c_j) \le T_j + D_j - c_j$

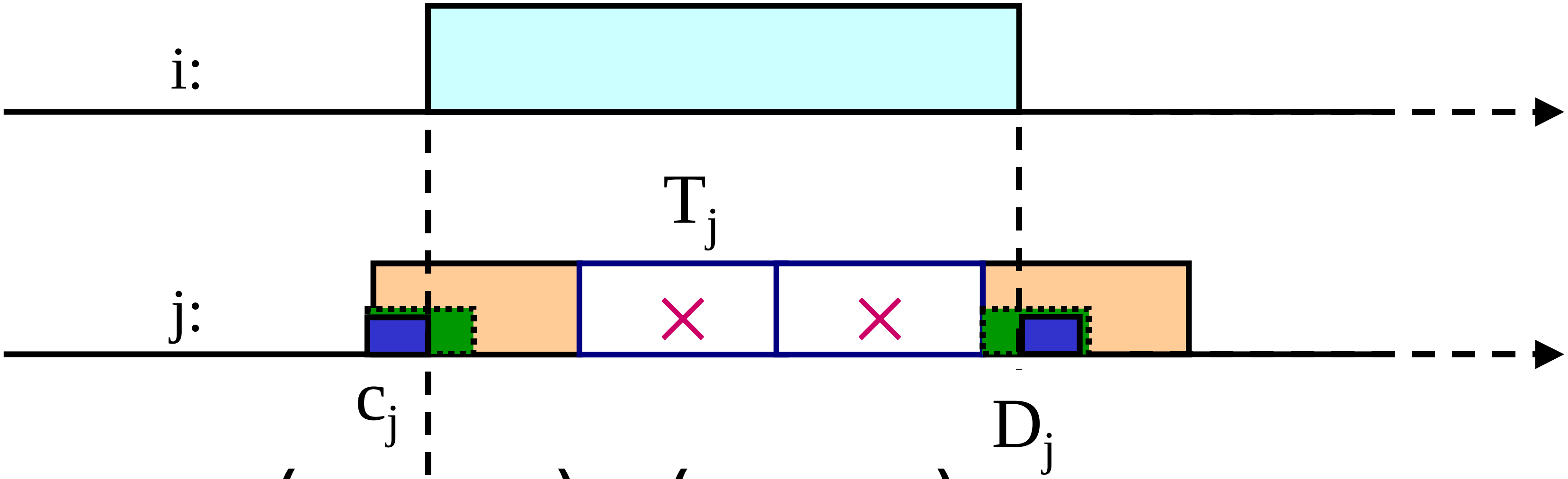
then no more than 1 miss

# When happens 1 deadline miss




$$\begin{cases} c_i - (T_j - c_j) > D_j - c_j, & \text{At least 1 miss} \\ c_i - (T_j - c_j) \leq T_j + D_j - c_j. & \text{No more than 1 miss} \end{cases}$$

# Generalization to *n* deadline misses




$$\begin{cases} c_i - (T_j - c_j) > (n_{j,i} - 1) \cdot T_j + D_j - c_j, \\ c_i - (T_j - c_j) \le n_{j,i} \cdot T_j + D_j - c_j. \end{cases}$$

which gives $\boldsymbol{x-1 \le n < x}$

# Minimum number of deadline misses

$$n_{j,i} = \left\lceil \frac{c_i + 2c_j - D_j}{T_j} \right\rceil - 1.$$

Minimum number of jobs that stream *j* misses while a job of stream *i* is being served

$$M = \left.\begin{bmatrix} \bullet & & & \bullet & \bullet & \bullet \\ n_{j,i} & & \bullet & \bullet & \bullet & \bullet \\ \bullet & \bullet & \bullet & \bullet & \bullet & \bullet \\ \bullet & \bullet & \bullet & \bullet & \bullet & \bullet \end{bmatrix}\right\} N \; x \; N$$

# Necessary conditions

Necessary Load condition

$$\sum_{i=1}^{N}\left[\frac{c_i}{T_i}\frac{m_i}{k_i}\right]\leq 1$$

Mutual feasibility condition

$$\forall \mathrm{i}, \mathrm{j} \leq \mathrm{N},$$

$$\mathrm{n}_{\mathrm{i},\,\mathrm{j}} \leq \mathrm{k}_{\mathrm{i}} - \mathrm{m}_{\mathrm{i}}$$

New Necessary Condition

# Matrix-DBP

| | (m, k) | Execution time | Period Deadline | Initial μ-pattern | Priority |
|---|---|---|---|---|---|
| Stream a | (4, 5) | 15ms | 30ms | 01111 | 2 |
| Stream b | (2, 5) | 2ms | 5ms | 00101 | 3 |

$$M = \begin{bmatrix} 0 & 0 \\ 2 & 0 \end{bmatrix}$$

$\text{Priority}_{a,b} = \text{DBP}_a - n_{a,b} = 2$

$\text{Priority}_{b,a} = \text{DBP}_b - n_{b,a} = 1$

# Simulation scenario

| | (m,k)-constraints | Job Process time: $c_i$ | Period ($T_i$)/ Deadline($D_i$) |
|---|---|---|---|
| **Stream 0** | (2,5) | 8/c | 12 |
| **Stream 1** | (4,5) | 10/c | 20 |
| **Stream 2** | (3,6) | 2/c | 5 |
| **Stream 3** | (1,5) | 4/c | 6 |

# Matrix of the scenario

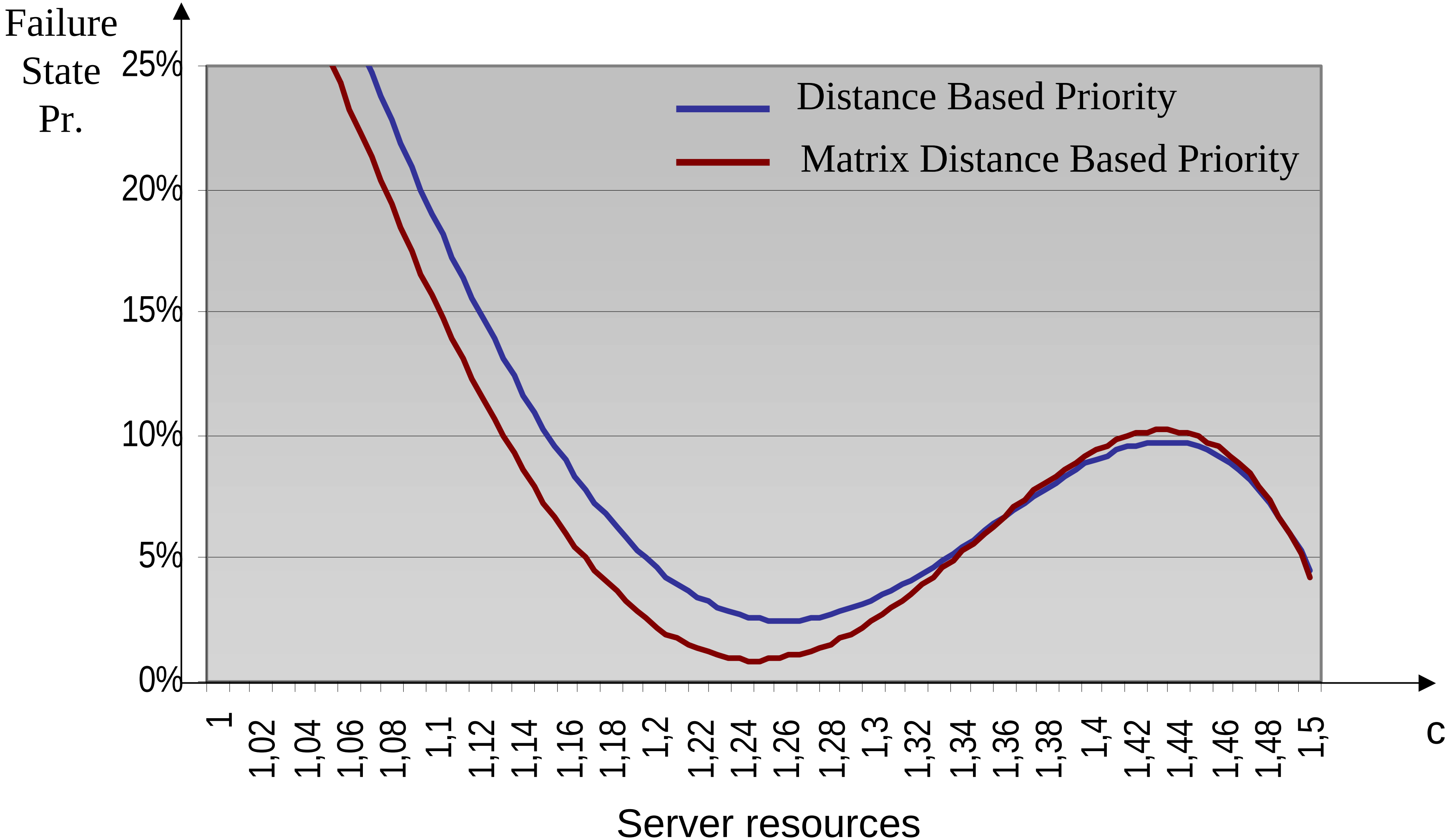
- When c = 1

$$M = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \end{bmatrix}$$

- When c = 1.5
Matrix-DBP becomes DBP

$$M = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

# Simulation result



# Contributions on (m,k)-firm

- Pointed out the drawback of the classic DBP when it is applied to a more general real-time context
- Provided an additional necessary condition call mutual schedulability test
- Proposed matrix-DBP to correct DBP

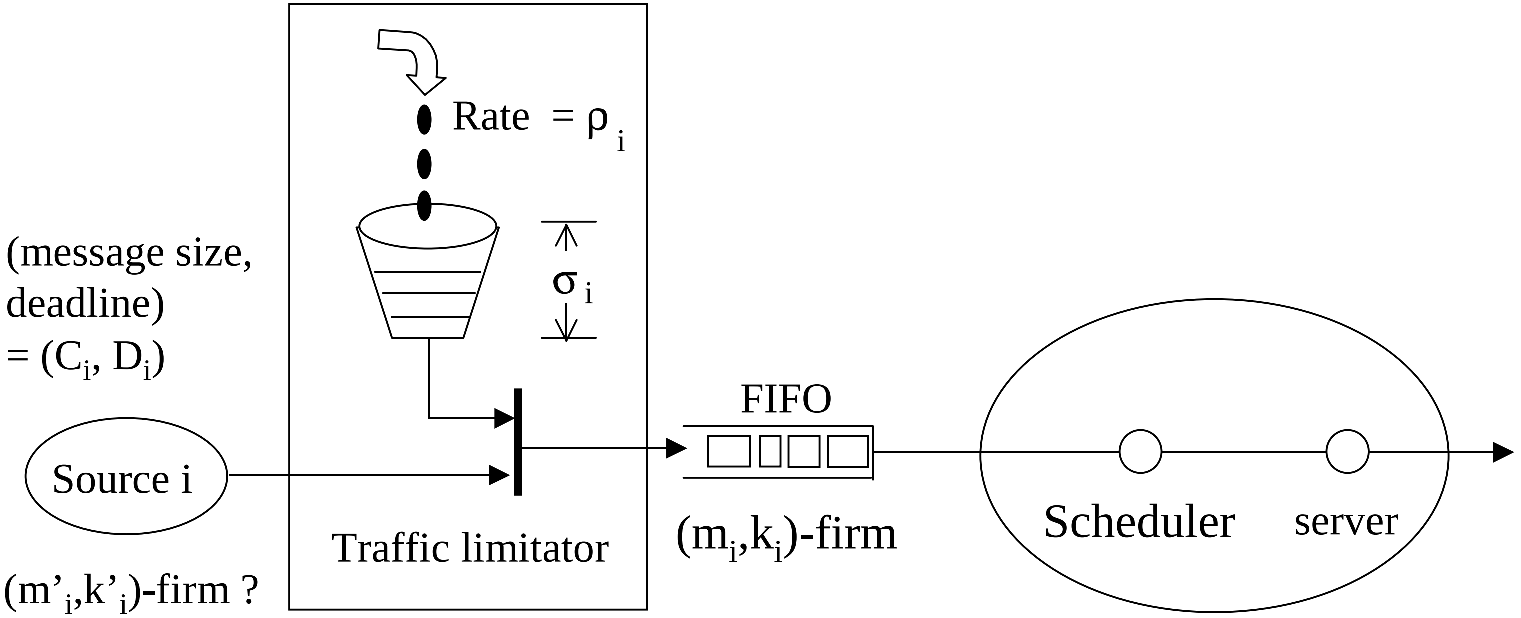
# Part 4: Future work

# On Matrix-DBP for (m,k)-firm

- Analysis of necessary condition on *c* for (m,k)-firm guarantee (i.e. find the value of *c* from which the system always has *0* failure state)
- Taking other criteria than the global failure state percentage (e.g., fairness in failure state percentage for each stream)
- Extension to multi-hops case by taking global deadline and local deadlines

# On (m,k)-firm

- Enhancement of DBP for aperiodic streams
- (m,k)-firm for a (σ,ρ) upper bounded traffic



# Application domains of (m,k)-firm

- Handling real-time traffic in Switched Industrial Ethernet (an Intranet) and in Internet
- Evaluating dependability in process control systems (in which we suppose that the state variables are over-sampled vs. Nyquist frequency)

# Questions and remarks?